How the Lessons Learned on Other Government Space Programs Apply to NASA's Constellation Program

NASA Project Management Challenge

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Introduction

- Over the past decade, there have been significant shifts in the nation's Space Industrial Base (SIB) and consequently its collective ability to support national space programs of all types
- These shifts are in response to various stimuli – including trends in government contracting – that simultaneously enable and constrain the kinds of support NASA can expect to receive for the Constellation Program
- Understanding the characteristics of the SIB landscape is critical for leaders in NASA and industry alike
- A number of systematic studies have been performed to determine critical success factors of complex programs in the National Security Space (NSS) sector, as well as to determine key reasons why space programs fail in an attempt to formulate and manage more successful programs in the future
  - The key findings of these studies are presented and discussed in terms of their applicability to the Constellation Program

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- Environment
- Space Industrial Base Studies
- Space Acquisition Studies
- Relevance to NASA
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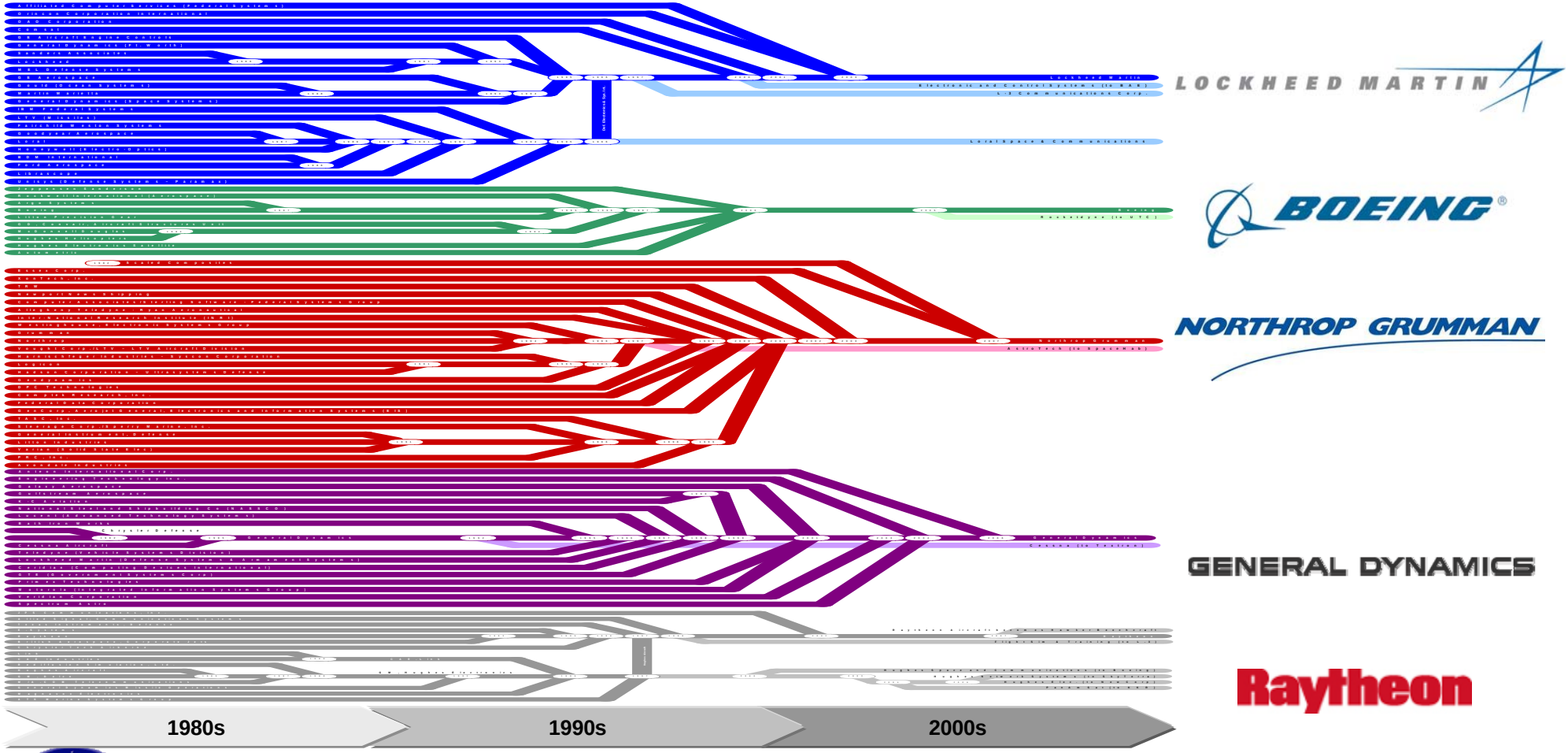
Industrial Base Environment – Aerospace Industry Consolidation

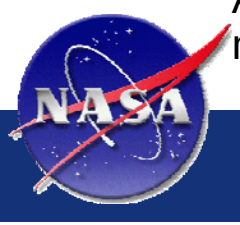


Industrial Base Environment

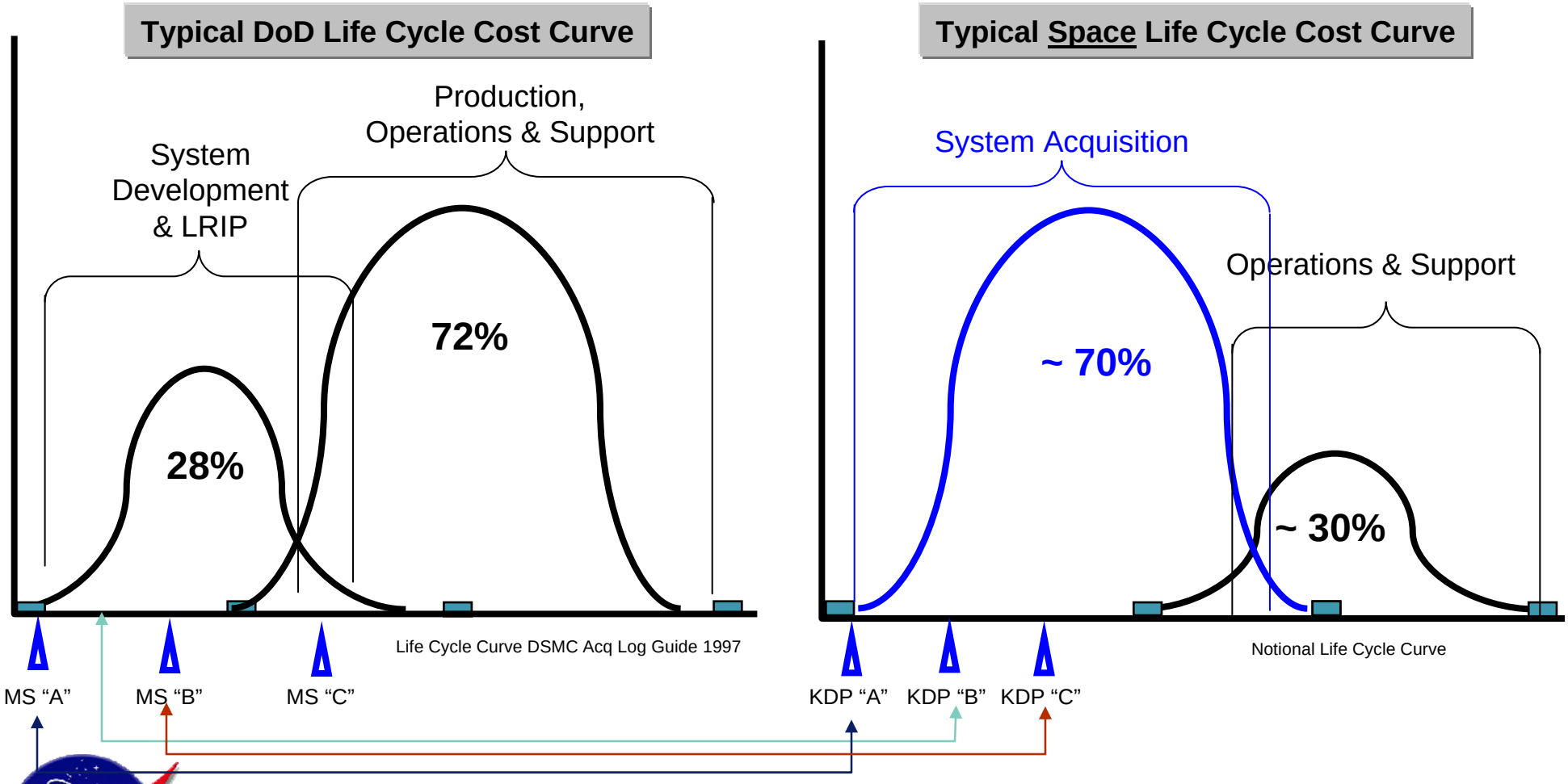
- To deal with excess capacity in the 1990s and early 2000s, industry underwent a series of mergers and acquisitions
  - Only a handful of primes remain, limiting competition. Primes were deep in debt due to this consolidation activity, but have experienced strong recent recovery due to increased defense spending
  - Similar reductions occurred in the sub-tier. In some cases, critical sub-tier suppliers with unique expertise and capability were lost or put at risk
- The challenging financial situation, combined with a smaller number of Government procurements, led to ***"must win"*** behavior in industry
  - Competing successfully on major programs became "life or death" for industry, ***resulting in extreme optimism in the development of cost estimates and program plans***
  - This cost optimism had at least one surprising consequence – during one stretch, the incumbent was unseated all but once in a series of over two dozen competitions (the incumbent retained in one instance only via a protest)
- Industry also has dealt with an aging of the aerospace workforce, challenges getting certain skills, and new worker recruitment and retention

National Security Space Environment

- All major National Security Space (NSS) missions undergoing upgrades this decade and next
  - Characterized by small numbers of large, expensive, multi-mission systems optimized for mission assurance and acquired via long development timelines
- Congress and the Defense & Intelligence leadership have lost confidence in the NSS acquisition community due to cost and schedule overruns in numerous programs. This was primarily a result of:
  - Acquisition reform of the 1990s and inadequacy of the Total System Performance Responsibility (TSPR) approach
  - Reduction in Government acquisition workforce size compounded by an aging workforce
  - Inadequate cost estimation by both Government and industry
- Recent Government responses have included:
  - "Back-to-Basics" block approach for acquisition of NSS systems
  - Operationally Responsive Space (ORS) program initiation
  - Cost estimating improvements, to include a Joint Government/Aerospace Industries Association (AIA) permanent council tasked with improving the fidelity of cost estimates on military space programs



DoD and Space Systems Life Cycle Comparison – Space Systems Acquisition Unlike Typical Government Programs



Source: Gen. Lance W. Lord, AFSPC, "Space Acquisitions: Achievements & Challenges," May 24, 2005

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Space Industrial Base Studies

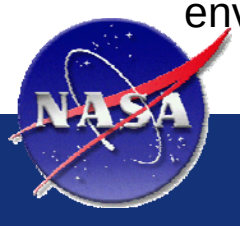
- 2000 – Space Industrial Base Study (SIBS): Assessed the sufficiency of the space industrial base to meet national security requirements over the next 15 years
- 2002 – Space Research & Development Industrial Base Study (SRDIBS): Assessed if the R&D sector of the SIB was sufficient to preserve space technology leadership
- 2004 – Solid Rocket Motor (SRM) Industrial Base: Determined composition and sufficiency of the current and projected solid rocket motor industrial base to meet the national security requirements for the next 6-10 years and if there will be adequate industry competition
- 2004 – Enabling Assured Access to Space: Assessed the DoD's plans and investments needed to better support "assured access to space" (i.e. achieving mission capabilities on orbit, enabling space operations)
- 2006 – ICBM Industrial Base: Quantitative assessment of the investment required to maintain or reconstitute the capabilities of the ICBM industrial base in various scenarios
- 2007 – Space Industry Export Control Impact Assessment: Assessed the impact of U.S. export controls on the health, competitiveness, and ability of the U.S. SIB to continue to support NSS requirements

Industrial Base Findings

- SIB can support the national security community's near-term requirements, beyond that there could be challenges in areas such as technological superiority and workforce
- The base will continue to experience mergers, consolidations, and exits – especially at sub-tier levels. Sub-tier suppliers are having problems due to low demand for components, particularly those that are space-qualified
- The nature of the base has changed dramatically over the past decade, evidenced by a shift in roles matched by a shift in Independent Research and Development (IRAD) investment. Primes now focus primarily on system integration with IRAD focused on integration innovation and doing less internal technology development.
  - In contrast, the sub-tier suppliers are the source of technology innovation, outspending the primes 3-to-1 in IRAD
- Export controls have had marginal financial impact to the SIB but had serious unintended consequences in that a large part of the base no longer engages overseas and significant foreign competition has sprung up

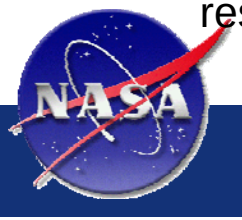
Industrial Base Findings

- Commercial sector
  - Expected demand in the commercial sector never materialized in the late 1990s, leaving the Government to bear the burden of maintaining the industrial base in the first part of this decade
  - Recent years have seen a significant resurgence in the commercial marketplace – in the satellite communications, remote sensing/imagery, and especially in commercial services
  - New, exciting potential for growth exists with the many "New Space" firms
- The U.S. base of human capital and knowledge is declining and is underscored by a lack of opportunities to grow future generations via sufficient space program experience
  - The Government and industry face challenges in finding and retaining high-quality program management leaders and workers due to declining funding and fewer program opportunities
- The relationships between industry, academia, and government are "sub-optimal" and analysis identified ways in which the various sectors had become more adversarial and often competed in non-traditional ways, with a blurring of the "lanes," or roles, they played
  - This shifting generally was to compete for funding and retain relevance in a tough environment



Industrial Base Recommendations

- Focus on retention of U.S. space technological leadership
  - Requires increased cross-sector Government attention, commitment, coordination, and integrated planning & execution to achieve and maintain
- Effective relationships between the stakeholders in the space industrial base are key if the U.S. is to remain technologically competitive
  - Recreate partnership with industry while maintaining sufficient competition
- Increase industrial base knowledge in acquisition strategy development and execution
  - Consider methods to develop and manage source selection strategies toward a vision of a sustainable and competitive industry structure
  - Consider methods to create more stable program time lines, multi-year funding or multi-year programs
  - Government must ensure sub-tier viability and competition. The range of options include both partnership (direct investment) and competition (monitoring of prime make-buy decisions and sub-tier competitions)
  - Direct investment, at all industry tiers, may occur for reasons such as to sustain RDT&E technical competition, maintain current capacity, or to increase independent cutting edge research



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Space Acquisition Studies

- 2002 – Space Systems Development Growth Analysis (SSDGA): Qualitative assessment based on interviews and a quantitative assessment based on a review of SBIRS-HI, AEHF, GPS-III. Developed an understanding of why development growth occurs. Determined whether the government is facing a systemic challenge or isolated events. Developed options that the government should consider to improve space system acquisition.

- 2003 – Defense Science Board/Air Force Scientific Advisory Board (DSB/AFSAB) Joint Task Force on Acquisition of National Security Space Programs: Assessed why cost growth and schedule delays occur, considering all aspects of the acquisition process. Assessed the space industrial base and the government's role, as well as examining the US national security dependence on space.

- 2006 – Defense Acquisition Performance Assessment (DAPA) Project: An integrated acquisition assessment considering every aspect of acquisition, including requirements, organization, legal foundations, decision methodology, oversight, and checks and balances, and developed a recommended acquisition structure and processes with clear alignment of responsibility, authority and accountability.

Changing Acquisition Environment

WAS → **THEN** → **NOW**

Pre-Acquisition Reform Era

- Significant accountability between the Government and the Contractor
- Government maintained system integrator role in most cases
- More Government specification
- Rigorous Government oversight…but…
- Poor Government system integration experiences
- Higher price and longer length of developments thought to be traceable in part to excessive Government oversight
- The thinking…We can do Better!!

Total Systems Performance

- Shifted accountability to the contractor
- Contractor to deliver end-to-end "systems"
- Contractors allocated performance requirements
- Contractors provided their own statements of work
- Contractors provided an approach to development using their own embedded processes (commercial best practices!)
- Government involvement held to a minimum and was only accountable for top level "systems performance"

Post-Acquisition Reform Era

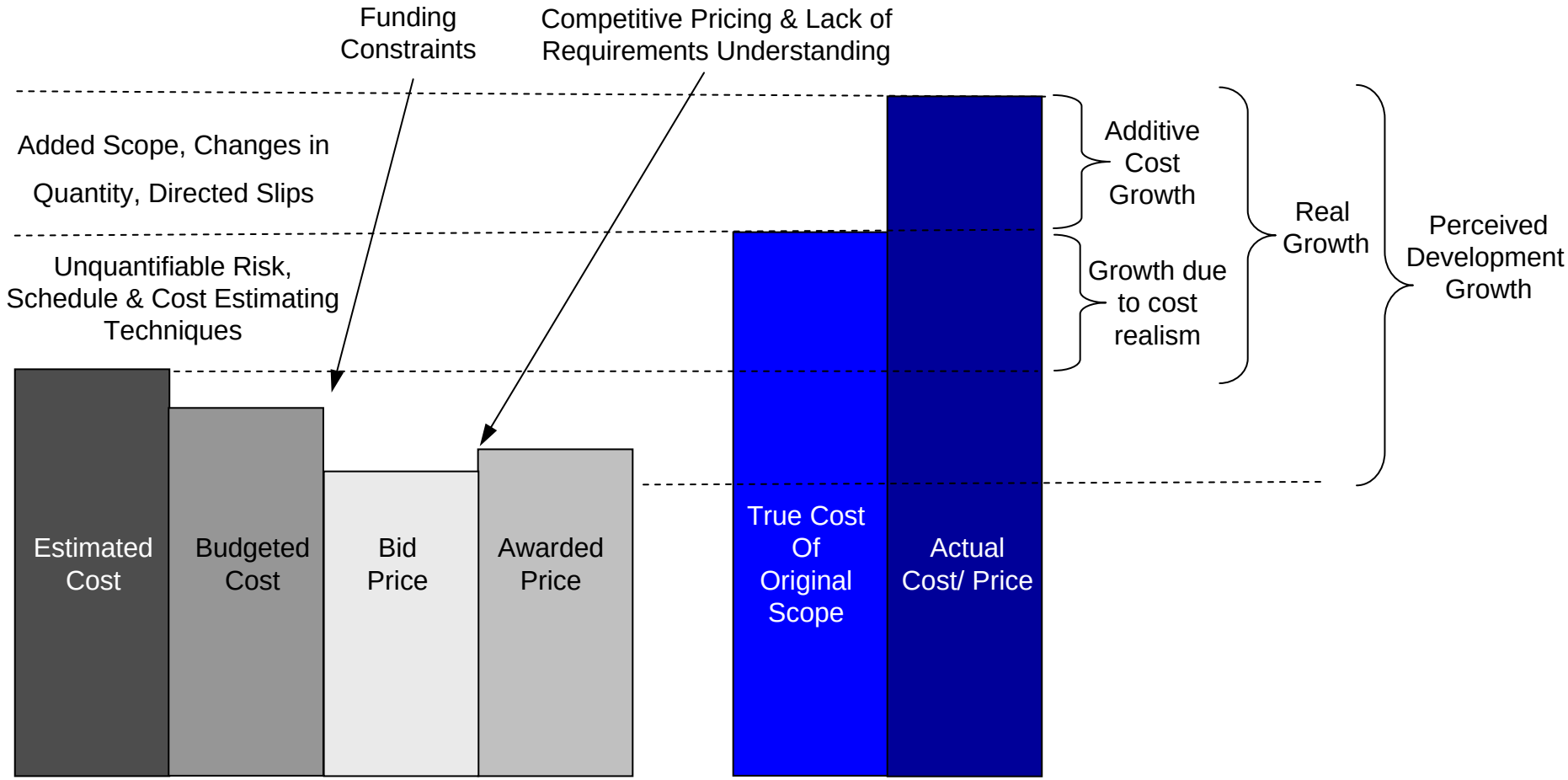
- Revitalized Government / Contractor collaboration
- Re-emphasizing solid Systems Engineering
- Growing our own credentialed Space Professionals and keeping Program Managers in place
- Re-baselining all Air Force Space Command (AFSPC) and Space and Missile Systems Center (SMC) Policies and Processes
- Independent Reviews
- Proactive oversight, flexible acquisition procedures

Source: Gen. Lance W. Lord, AFSPC, "Space Acquisitions: Achievements & Challenges," May 24, 2005

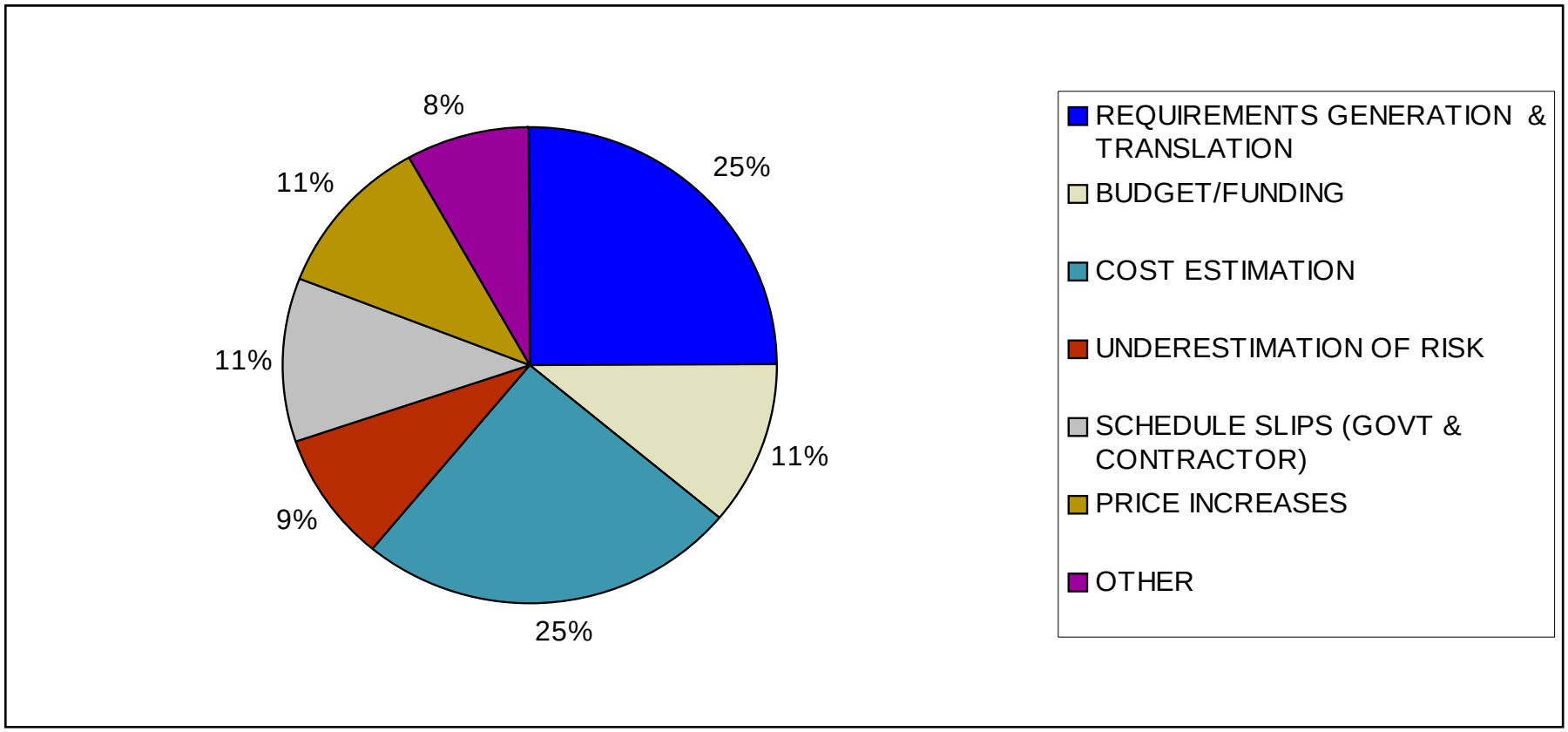
Space Acquisition Findings

- The Government's ability to lead and manage the space acquisition process has seriously eroded. Deficiencies also exist in industry implementation of space systems acquisition
- **Cost has replaced mission success as the primary driver** in managing space development programs
- Unrealistic cost estimates lead to unrealistic budgets and unexecutable programs
  - Under-funding in a given fiscal year causes work which ultimately must be accomplished in the future at a cost premium of as much as 3-to-1
- Undisciplined definition and uncontrolled growth in systems requirements lead to cost overruns
  - The scope of a new program cannot be totally determined and the tendency is to always under-scope
  - Requirements "understanding" and "clarification" virtually always result in additional scope
- An issue such as a test failure, parts problem, component delivery, etc. – while potentially small, has a large impact because of the "marching army syndrome."

Development Growth Quantitative Framework

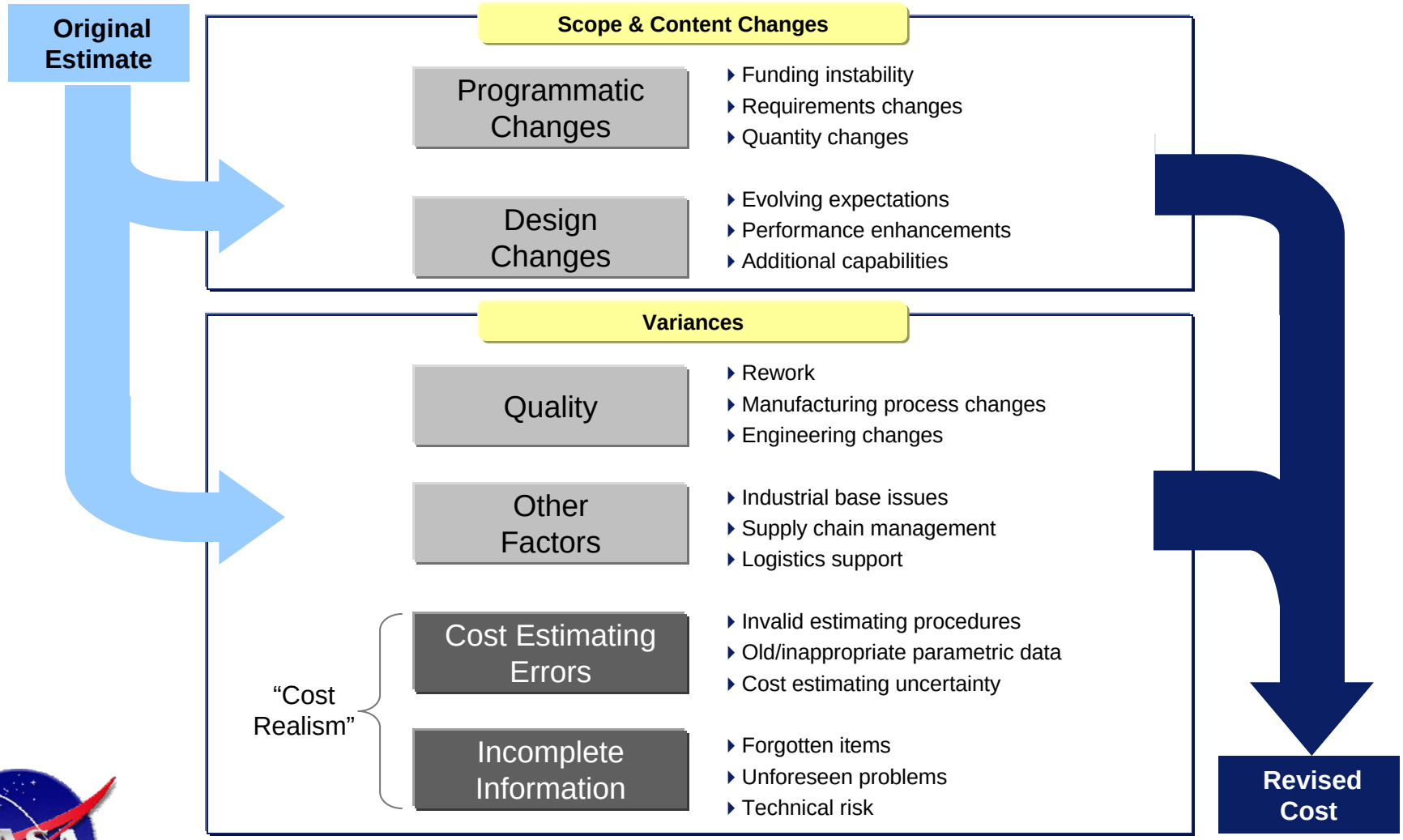


Development Growth Causes *(Quantitative Analysis)*

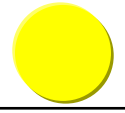


Comparison of total dollars growth by category for two space programs at a point in time. Total Value of Pie is $6.1B

Sources of Error in Cost Estimates



Space Acquisition Findings & Resulting Government Action (from Tom Young's One Year After Review of the DSB/AFSAB's Impact)

Original Finding	Actions / Response	Status
1. Cost #1, not mission success	▸ Revitalized focus on mission assurance ▸ Independent Readiness Review Team, Flight Readiness Review, Aerospace Watchlist	
2. Unrealistic estimates=unrealistic budgets=unexecutable programs	▸ Rigorous reviews: Independent Program Assessments, Program Management Reviews, Independent Cost Analysis ▸ Continue to improve cost estimating models & tools	
3. Undisciplined system requirements	▸ "Urgent & Compelling Rqmts" Process ▸ Disciplined Configuration Management	
4. Gov't space acquisition capabilities seriously eroded	▸ Program Managers extended to four-year tours ▸ Extensive new system engineering and education & training programs	
5. Industry failed to implement proven prgm management and systems engineering practices	▸ Reintroduction of specifications & standards ▸ Contractor Benchmarking / Executive Committees	

"Extraordinary cultural change…in only one year."

- Tom Young, July 2004

Source: Gen. Lance W. Lord, AFSPC, "Space Acquisitions: Achievements & Challenges," May 24, 2005

Space Acquisition Recommendations

- Budget to a most probable (80/20) cost which includes a reserve of 20-25% management reserve.
  - Management reserve should not be used for new requirements
- Approach requirements in an evolutionary manner.
  - Plan for and accept incremental improvements
- Develop technology roadmaps, invest in establishing technology readiness levels for each program, and advocate a technology transition program.
  - Demonstrate technologies in relevant environments, product design demonstrated before CDR
  - Annually reevaluate and confirm critical technology and schedule paths
- Build risk reduction activities into acquisition strategy that builds upon long term planning.
- Utilize senior advisory reviews at critical acquisition milestones with experienced, respected outsiders.

Space Acquisition Recommendations

- Emphasize comprehensive initial budget estimate development for new systems
  - Insist that technology and acquisition management personnel participate in initial budget estimates
  - Understand, state, and track technical, cost, system and process assumptions
- Emphasize cost realism over bid cost
  - Source selections should evaluate contractor cost credibility and use the estimate as a measure of contractor technical understanding
  - Emphasize systems engineering, early testing and other risk reduction activities as part of technical approach
  - Consider penalties for unsubstantiated optimism (negative scoring)
  - Establish ways to better facilitate and communicate technical, operational, and system requirements to contractors
- Conduct effective independent cost estimates and program assessments, and incorporate the results into the program budget and plan.

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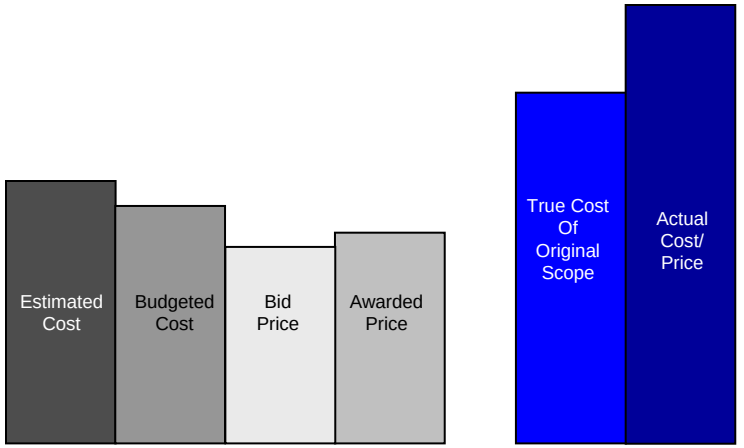
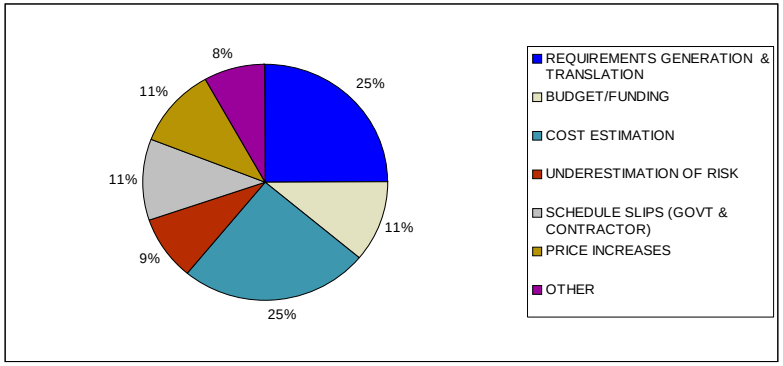
NASA is Vulnerable to Many of the Same Issues Faced by DoD and National Security Space Programs

- The same Space Industrial Base supports all NASA development programs as it does the other Space segments – but perhaps with even fewer players in the game
- Most of the same behaviors observed in the National Security Space segment are consistent with observations in the NASA segment
  - All competitions represent "Must-win's" between the limited pool of "Primes"
  - Strong cost pressures exist in most all procurements
  - NASA procurement organizations across the agency are experiencing their busiest acquisition seasons in memory – taxing their ability to plan and complete acquisitions while also managing on-going critical contracts
- It is not unreasonable to expect that NASA could experience similar "unintended consequences" as did the DoD and the National Security Space segments have in the recent past
- Because of these factors, it is also not unreasonable that the lessons learned in the other segments would have similar benefits in the NASA environment

The Constellation Program is Vulnerable to Many of These Issues Because of its Basic Formulation

- Constellation will constantly exist in a budget constrained situation for it's entire life cycle
  - Highly ambitious goals and a broad and complex architecture
- This can lead to aggressive cost estimates and proposed costs which will have to be managed through disciplined program management practices
- Constellation's complex architecture with multiple spacecraft-spacecraft and spacecraft-ground systems ICD's and its evolutionary system develop plan can lead to requirements immaturity/change as well as requirements creep further compounding potential development cost over-runs





The Constellation Program is Vulnerable to Many of These Issues Because of the Challenges it Faces with It's Workforce

- NASA and its contractors, like the other Space Segments, have to deal with an aging of the aerospace workforce, challenges getting certain skills, and new worker recruitment and retention
  - This is further exacerbated as the "Apollo generation" moves further into retirement and the "Space Shuttle generation" completes its transition out of the workforce over the next 5 years
- Program Management and Systems Engineering skills are in short supply across the Aerospace Industry and competition to capture these will be keen across the entire industrial base
  - These skills represent the highest leverage capabilities needed protect against cost and schedule over runs in light of the threats on the previous pages
- The broad geographic footprint of Constellation will strain communications and increase integration risk as well as potentially cause late requirements growth

The Constellation Program is Vulnerable to Many of These Issues Because of the Evolutionary Nature of Its Architecture

- Interfaces for elements in development today will be to elements that will not be designed for many years
  - Requirements turbulence later in development and operations phases is possible
- Technologies will become obsolete and need to be replaced/upgraded at multiple points in the life cycle of a Project and new, unproven, technologies needed for Lunar/Mars missions
  - Risk of becoming "hostage" to a high risk technology development program will be higher
- The geographic distribution of development work across multiple centers when Agency-wide processes best practices are not widely practiced increases risks
  - Technical integration risk higher due to incompatibility of specs, standards and processes across centers
  - Approaches, standards and levels of expertise for cost estimating vary widely across centers decreasing ability to develop high fidelity cost estimates at Program Milestones

Lessons learned from other segments may prove useful in mitigating Program and Project risks

Questions?

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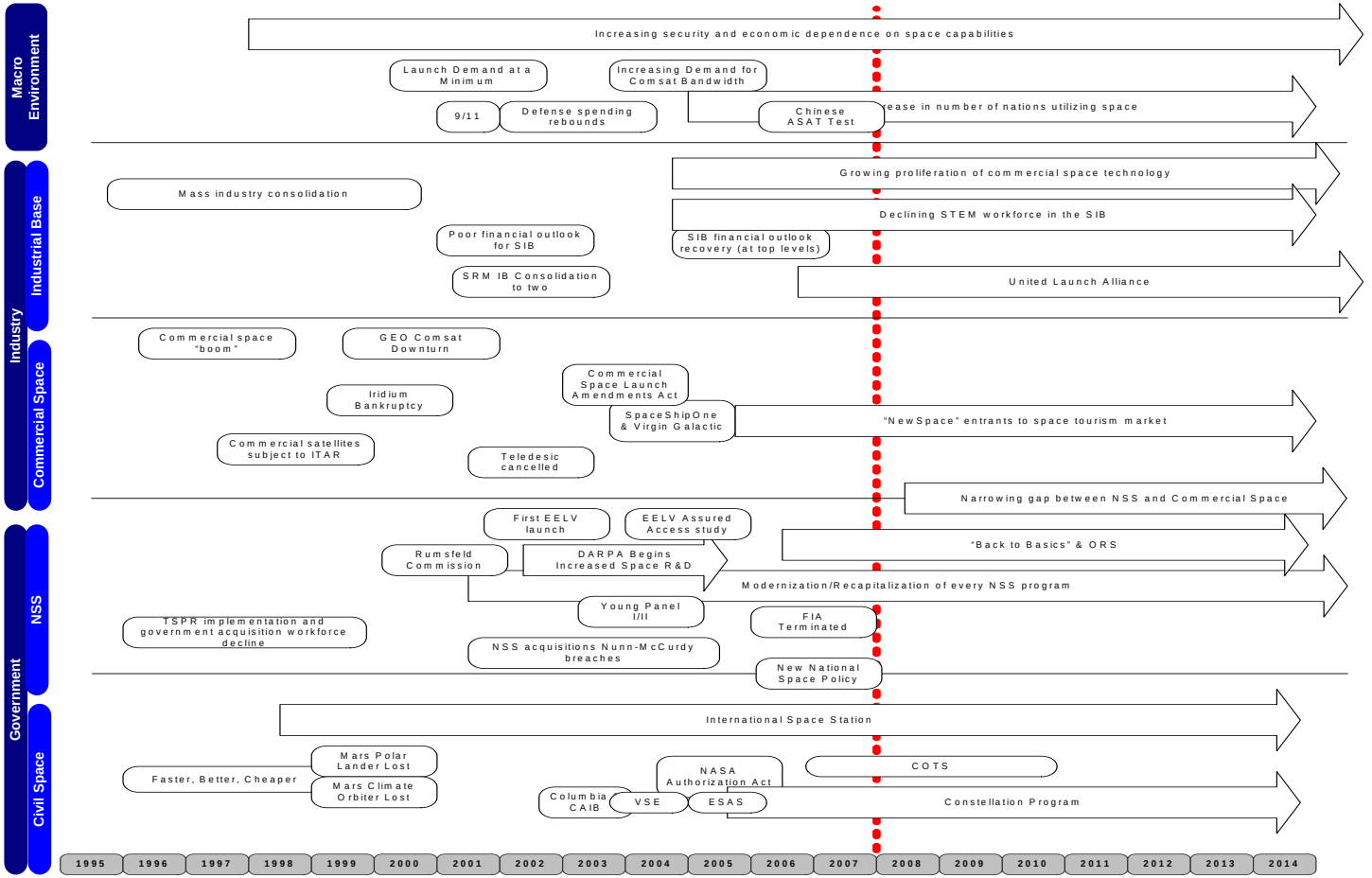
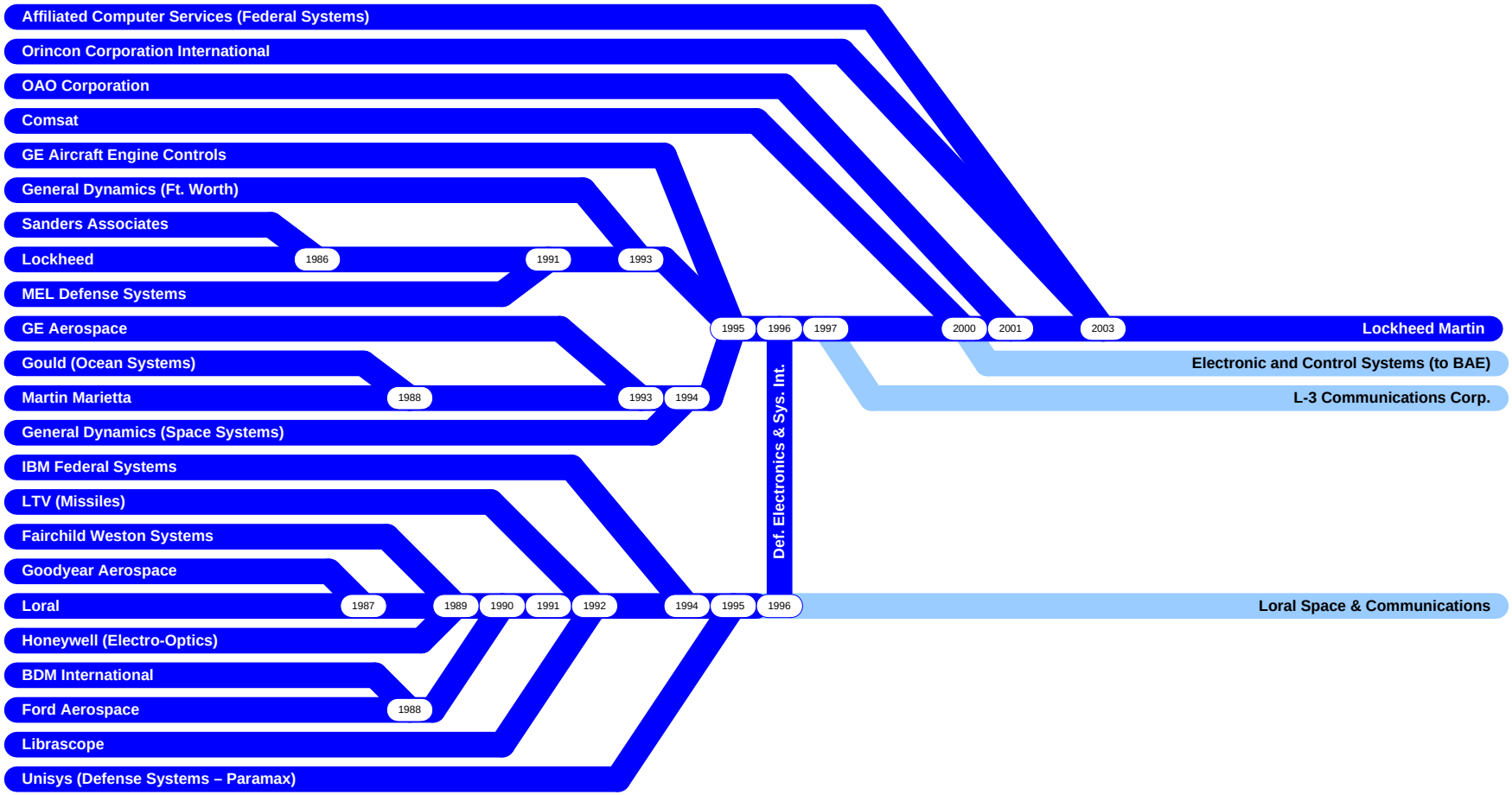
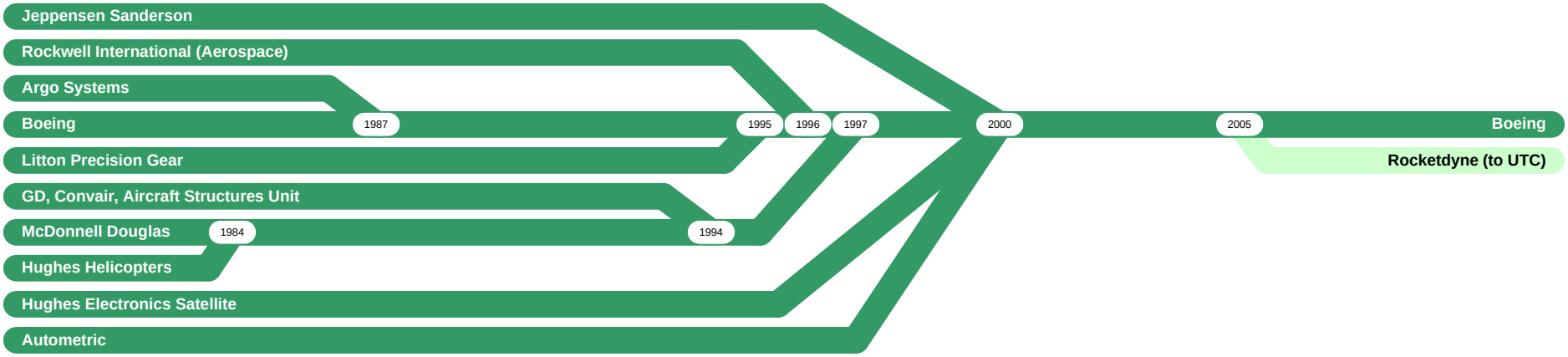
Space Environment – Top Level View



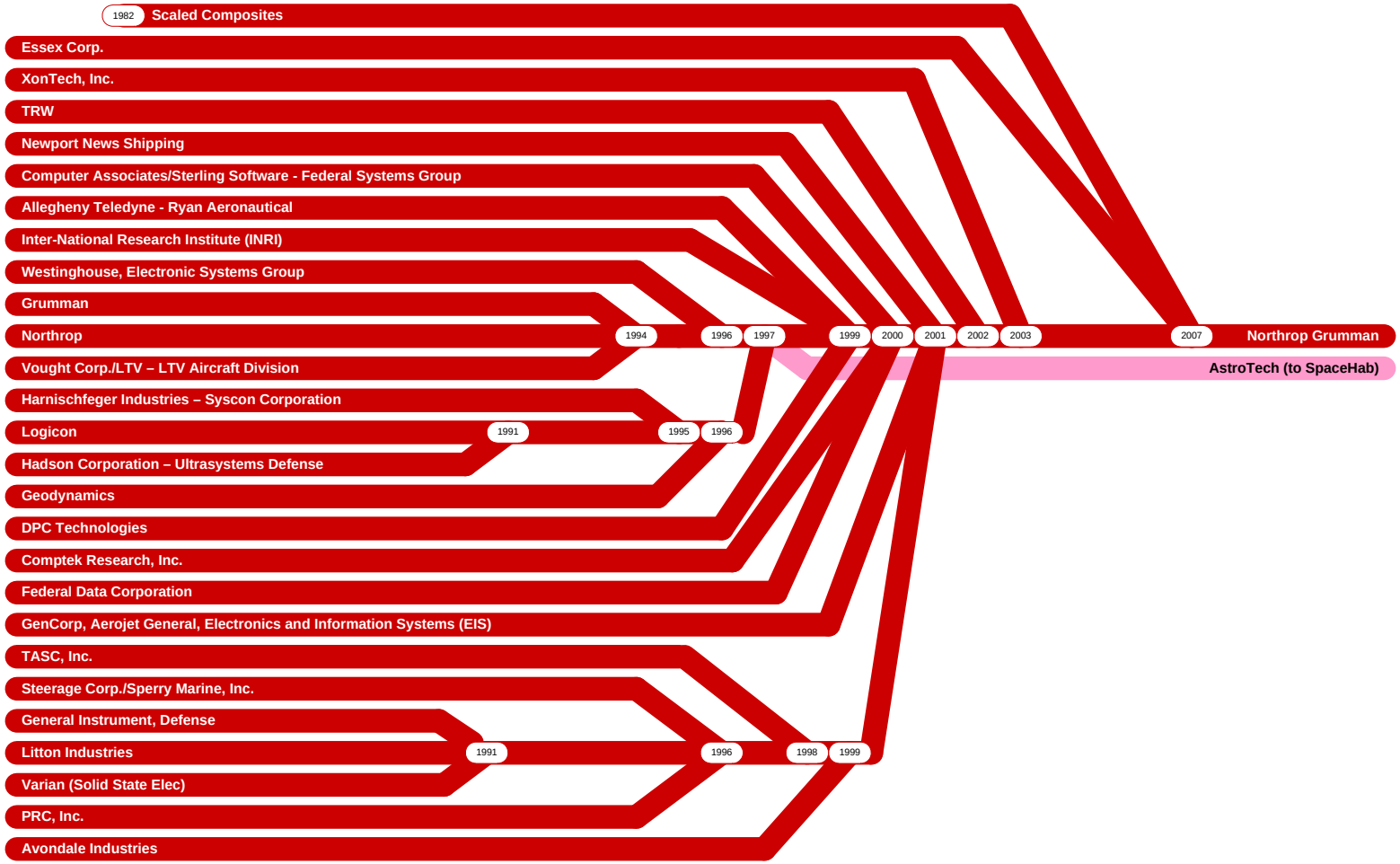
Aero Industry Consolidation – Lockheed Martin



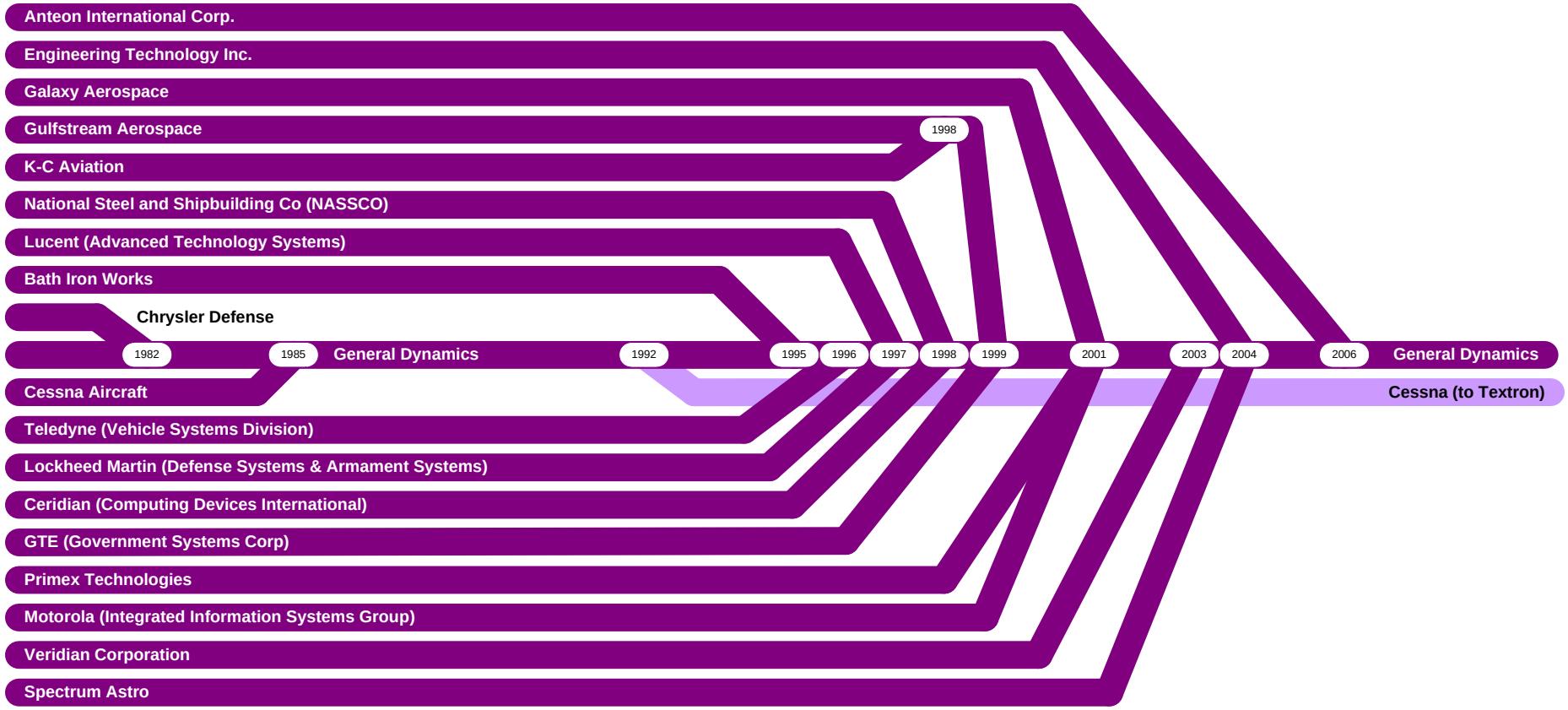
Aero Industry Consolidation – Boeing



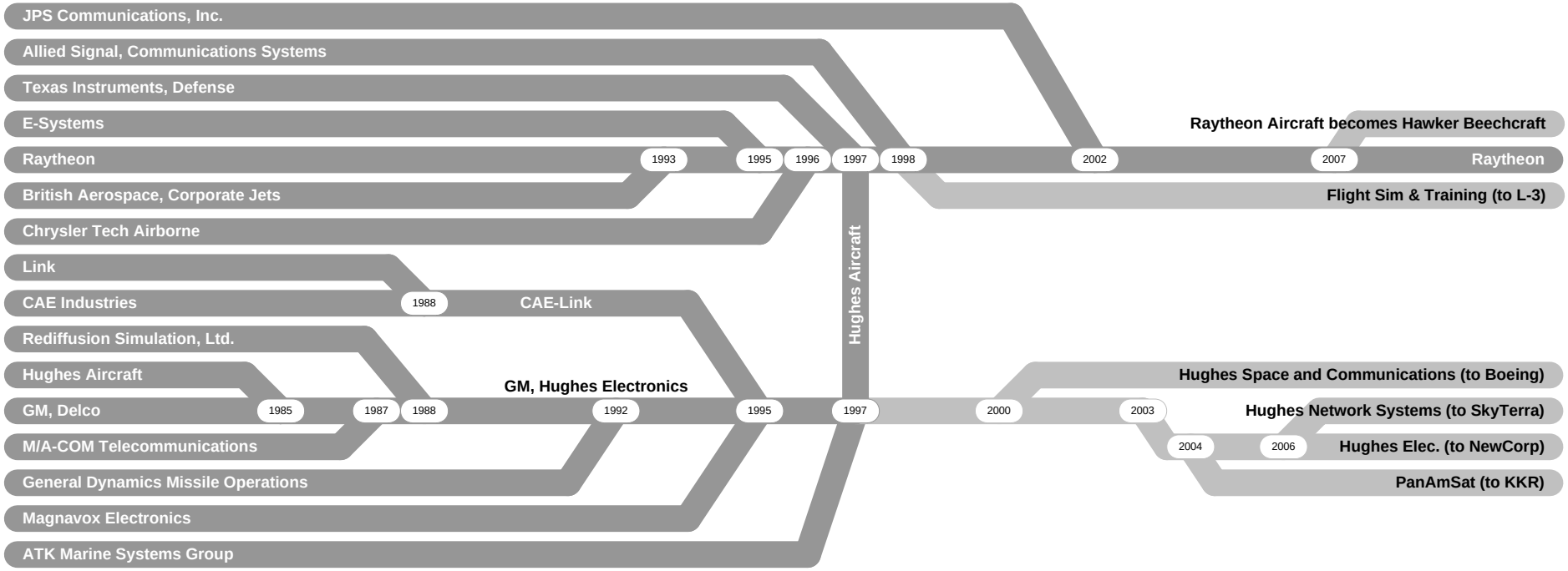
Aero Industry Consolidation – Northrop Grumman



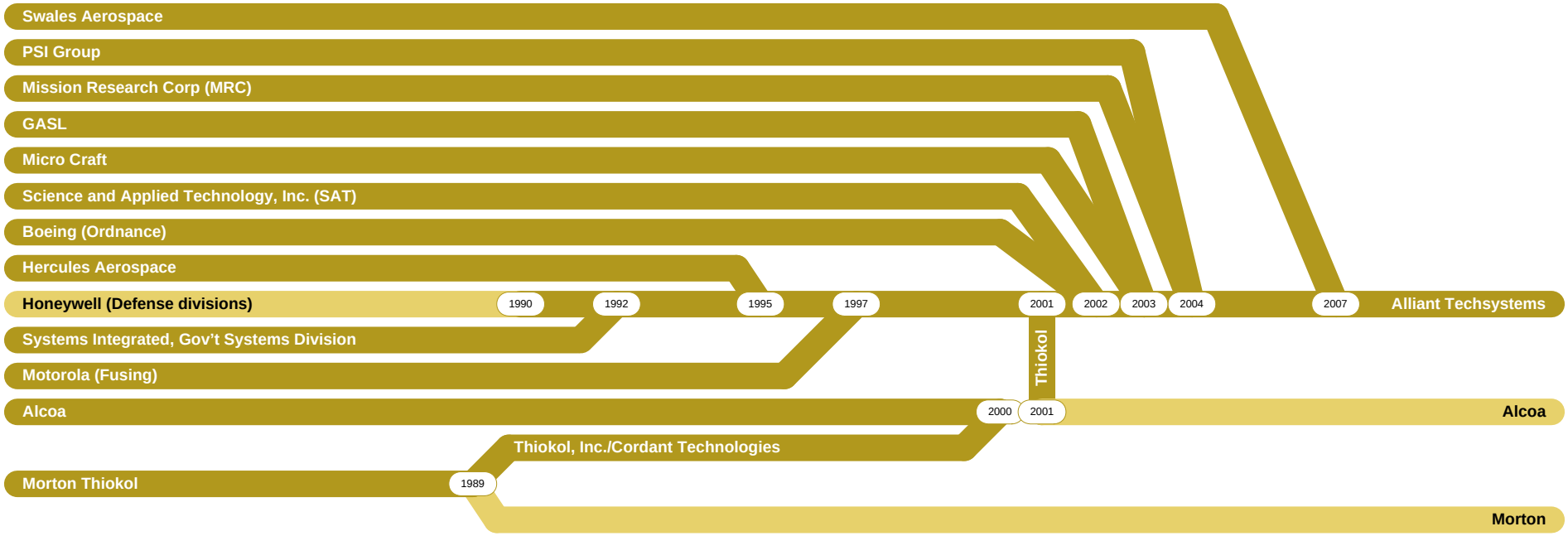
Aero Industry Consolidation – General Dynamics



Aero Industry Consolidation – Raytheon



Aero Industry Consolidation – Alliant Techsystems (ATK)



Government's Role in Space Acquisition Program Management

- Manage overall Acquisition process
- Budget and allocate funds
- Establish, manage and control requirements
- Manage and control budget, including reserve
- Approve Program Definition
- Assure responsible risk management
- Participate in trade studies
- Assure engineering "best practices" are utilized in program implementation
- Manage contract including contractual changes
- Sustain a viable and competent workforce

Source: Task Force Briefing, "Acquisition of National Security Space Programs," November 19, 2002.

Attributes of a Healthy Space Acquisition

- Trust between government organizations as well as with contractors
- A government and industry workforce experienced in the space discipline that includes both senior personnel and a pipeline of new talent
- A validated set of requirements with a limited number of documented, realistic assumptions based on an understood and approved CONOPS
- Continued and sustained support by senior leadership - active user community support and involvement – enduring decisions - A champion
- Authorities commensurate with responsibilities – accountabilities flowed down and supported by leadership
- An acquisition strategy that balances cost, schedule, and performance risks and a source selection process which delivers a realistic performance, schedule and cost baseline

- Adequate, stable and properly phased funding including an acknowledged and defendable management reserve to include a sufficient margin particularly at the outset of the program
- A well defined and realistic acquisition program baseline supported by a thorough and in depth CARD developed with contractor participation, if applicable - also a historical descriptive timeline
- A well-founded and funded, proactive risk management program
- Repeatable "best of class" acquisition and program management processes which can be tailored
- Meaningful metrics that help determine the current and future health and status of the program
- A healthy (sufficient and competitive) industrial base motivated to provide executable programs and incentivized to deliver on commitments

Development Growth Causes

Flawed Program Planning

- Requirements
- Initial planning
- Acquisition Strategy

Competitive Environment

- Aggressiveness
- Source Selection

Corporate Process Directed Actions

- External and frequent
- Little flexibility to respond

The ability to respond to development growth is compounded by acquisition workforce problems

Sources

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